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Investigation of Potential Benefits in Biorefinery Processes by the Use of Aquaporin Inside™ Membrane Separation

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Great interest has been attracted towards 2nd generation biorefineries, since they can potentially provide a sustainable way for production of biofuels and bio-based chemical. However, in most of the cases, the production is not economically or environmentally sustainable. The latter is a result of extensive water use for substrate dilution in order to reduce potential inhibition effects during the bioconversion process [1].

The aim of this study is to investigate the water recovery potential by using forward osmosis and Aquaporin Inside™ membranes [2] and test the integration of this biomimetic system in different biorefinery processes. The greatest benefit of this technology is the low energy operational demands since the main driving force is the osmotic pressure difference between the two sides of the membrane. For the scope of this study, two fermentation cases were considered: i) wet-exploded, enzymatically hydrolyzed wheat straw (Biogasol, Denmark) with *C. tyrobutyricum*, strain DSM 2637 and ii) crude glycerol (Daka EcoMotion, Denmark) with *C. pasteurianum*, strain DSM 525. A preliminary techno-economic analysis was performed with Superpro Designer® (Intelligen, Inc) and consecutively a 2³ Inscribed Central Composite (ICC) design was applied with the use of Unscrambler® x 10.3 (CAMO, Norway). The variables to be investigated were a) the pump cross flow velocity and b) the osmolality difference between the feed and draw solution (expressed as dilution factor). The relevant values are shown in Table 1.

Table 1. Range of design variables for optimization of forward osmosis separation

| Parameter | Coded factor levels | | | | |
|--|---------------------|------|-------|------|-------|
| | -a | -1 | 0 | 1 | a |
| Pump cross-flow velocity (ml s ⁻¹) | 4.46 | 6.53 | 11.51 | 16.5 | 18.57 |
| Dilution factor | 70 | 59.9 | 35.5 | 11.1 | 1 |

Crude glycerol showed a higher potential compared to wheat straw as the water fluxes obtained in preliminary tests were substantially higher in the first case. Furthermore the preliminary techno-economic analysis revealed that a 50% water recovery could result up to 35% reduction of the downstream processing cost (represented by a distillation unit). Finally, the investigation of the most important parameters and their correlation with the water flux will bring this method one step closer to its in-line integration with the bioconversion process.

To sum up, Aquaporin Inside™ biomimetic separation technology have shown great potential for providing a sustainable solution for water recovery during bioconversion processes. The main benefit of this process is the relatively low energy demand that can be proved crucial for the viability of the biorefinery industry.

- [1] S. Nicolaou, S. Gaida, and E. Papoutsakis, "A comparative view of metabolite and substrate stress and tolerance in microbial bioprocessing: from biofuels and chemicals, to biocatalysis and bioremediation," *Metab. Eng.*, vol. 12, no. 4, pp. 307–331, 2010.
- [2] Y. Zhao, C. Qiu, X. Li, A. Vararattanavech, W. Shen, J. Torres, C. Hélix-Nielsen, R. Wang, X. Hu, A. G. Fane, and C. Y. Tang, "Synthesis of robust and high-performance aquaporin-based biomimetic membranes by interfacial polymerization-membrane preparation and RO performance characterization," *J. Memb. Sci.*, vol. 423–424, pp. 422–428, 2012.